

THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPELLANT: THADDEUS SCHROEDER et al )  
 )  
 ) Group Art Unit:  
 ) 3611  
SERIAL NUMBER 09/663,030 )  
 )  
 ) Examiner:  
 ) D. De Pumpo  
FILED: September 15, 2000 )  
 )  
FOR: PIEZORESISTIVE TORQUE SENSOR )

**RECEIVED**

**JUN 11 2002**

**AMENDED APPEAL BRIEF UNDER 37 CFR 1.192(d)**

**GROUP 3600**

1. THE REAL PARTY IN INTEREST

The real party in interest in this appeal is Delphi Technologies, Inc. Ownership by Delphi Technologies, Inc. is established by assignment document recorded for this application on January 27, 2000 on Reel 011423, Frame 0870.

2. RELATED APPEALS AND INTERFERENCES

Appellant knows of no related patent applications or patents under any appeal or interference proceeding.

3. STATUS OF CLAIMS

Claims 1 - 25 are pending in the application. Claims 10 - 25 have been withdrawn from consideration. Claims 1 - 9 stand finally rejected. In particular, Claims 1, 2 and 9 stand rejected under 35 U.S.C. 102(b) as being anticipated by Taig (4,655,092). Furthermore, Claims 3 - 8 stand finally rejected under 35 U.S.C. 103(a) as being unpatentable over Taig in view of Brosh et al and further in view of Buhl, et al.

#### 4. STATUS OF AMENDMENTS

There have been no amendments filed subsequent to receipt of the final office action.

#### 5. SUMMARY OF INVENTION

The disclosure relates generally to an automotive steering system with a torque sensor. Current methods of measuring the torque applied to an automotive steering shaft are of the compliant kind and are typically accomplished by use of a torsion bar as part of the shaft, joining an upper and lower section thereof. The torsion bar is made of material with known mechanical properties and hence has known compliance. Thus, the applied torque can be calculated from a measured angular displacement,  $\Delta\theta$ , of the torsion bar (usually in the range of plus or minus a few degrees). The calculated torque is applied to a controller which then directs an electric steering torque assist motor to provide assist torque to the steering shaft.

However, this method introduces additional compliance into the control system - an undesirable parameter affecting the speed of response and the feel of the steering action. This method also suffers from the added expense of additional parts and the fabrication thereof.

The problems of the prior art are overcome by providing a simplified torque sensor for direct sensing of the torque applied to a shaft to which the sensor is connected. In particular it is desirable to provide a faster and more accurate non-compliant measure of the torque applied to the shaft by the driver.

This invention comprises an automotive steering system 100 comprising a shaft 102 which is linked to a set of road wheels 118. (*Fig. 1; p. 6, l8 - 12*). The shaft 102 includes a slot 103 parallel to the axis of the shaft 102 and located at a single peripheral location about the surface of the shaft (*Figs. 11, 14A - 14D; p. 8, l. 16 - 25*). A piezoresistive sensor 120 is positioned within and along the length of the slot 103 and is responsive as a cantilever beam to torque applied to the shaft 102. (*Fig. 4; p. 7, l. 12 - 21*). The piezoresistive sensor 120 is operative to provide as output a signal 120a indicative of

the applied torque. A controller 110 is in signal communication with the sensor 103 and is operative to accept as input from the sensor 103 the signal 120a indicative of the torque applied to the shaft 102 (*Fig. 1; p. 6, l. 14 - 19*). A motor 112 is coupled to the shaft 102 and is in signal communication with the controller 110. The motor 112 is operative to accept as input from the controller 110 a command 110a to apply torque to the shaft 102. (*Fig. 1; p. 6, l. 14 - 19*).

6. ISSUES

There are two issues on appeal:

- i. whether the Examiner's rejection of Claims 1, 2 and 9 under 35 U.S.C. § 102(b) as being anticipated by Taig is improper; and
- ii. whether the Examiner's rejection of Claims 3 - 8 under 35 U.S.C. § 103(a) as being unpatentable over Taig in view of Brosh et al. and further in view of Buhl et al. is improper

7. GROUPING OF CLAIMS

There are two groups of claims. Claims 1, 2 and 9 comprise the first group, which stand or fall together, under the Examiner's contested rejection of these claims under 35 U.S.C. §102(b) as being anticipated by Taig. Claims 3 - 8 comprise the second group of claims, which stand or fall together, under the Examiner's contested rejection of these claims under 35 U.S.C. §103(a) as being unpatentable over Taig in view of Brosh et al. and further in view of Buhl et al.

8. ARGUMENT

**A. The Examiner improperly rejected Claims 1, 2 and 9 under 35 U.S.C. §102(b).**

Taig does not teach each and every element of Appellant's claimed invention. The Appellants respectfully submit that the prior art of Taig and the invention encompassed by

the present Claims 1, 2 and 9 of this application are fundamentally different in structure and thus in their resultant mechanical effects.

Under the first grouping of claims, the issue is whether the Examiner improperly rejected independent Claim 1. To anticipate a claim under 35 U.S.C. § 102, *a single* source must contain *all* of the elements of the claim. *Lewmar Marine Inc. v. Barient, Inc.*, 827 F.2d 744, 747, 3 U.S.P.Q.2d 1766, 1768 (Fed. Cir. 1987), *cert. denied*, 484 U.S. 1007 (1988). Also, a claim is anticipated, and therefore invalid under 35 U.S.C. § 102, if each claimed element is found in a single prior art reference. *Scripps Clinic & Research Foundation v. Genentech, Inc.*, 927 F.2d 1565, 1576 (Fed. Cir. 1991); *Carella v. Starlight Archery and Pro Line Co.*, 804 F.2d 135, 138 (Fed. Cir. 1986). There must be *no difference* between the claimed invention and the reference disclosure, as viewed by an ordinary artisan. *Scripps Clinic & Research Foundation v. Genentech, Inc.*, 927 F.2d at 1576.

In response to the first Office Action, Claim 1 was amended to include the recitation of a piezoresistive sensor *responsive as a cantilever beam*. With regard to the issue of the cantilever beam, the Examiner states, in the Final Office Action of November 5, 2001, that:

“This function is taught by Taig. Clearly, one end of the beam will move with respect to the other end when the shaft is subject to torsional forces.”

The Appellants believe that this is incorrect and that Taig does *not* teach a cantilever beam, nor a sensor that could possibly be *responsive* as a cantilever beam as required in Claim 1. The sensor in Taig is shown in Figure 2. Torsional member 20 fits into the opposing slots 100 and thus straddles axis 82 and input member 16. A tab portion 77 of torsional member 20 engages slot 64 in output member 18. In Figure 2 the Board's attention is directed to torsion member 20 which “is elongated, and flat with a central portion 66 of reduced lateral dimension.” (*Col. 3, lines 45 – 47*). This central portion, having a reduced lateral dimension, defines an area parallel to the axis 82 and located between the tabs designated by the reference numerals 70 and 74. This area might best be

referred to as a “void area” because there is in fact nothing there. This fact is important and will be addressed in a moment. Furthermore, “A strain sensitive element such as a strain gauge 94 is fixedly secured to one of the surfaces of the torsion member in conventional manner.” (*Col. 4, lines 7 – 9*). Also as seen in Figure 2, the strain gauge 94, which is the sensing element in Taig, is situated over the *central portion* 66 of the torsion member 20 and thus also *straddles* axis 82. This fact bears directly upon the nature of the response of the strain gauge 94 to an applied torque.

The nature of the sensor in Taig is such that, upon the application of a torque to the steering column, i.e., to the cylindrical input member 16, there will be a slight rotation of input member 16 with respect to output member 18 about the axis 82. As a consequence, torsional member 20, which is positioned within slot 100 and symmetric about axis 82, will twist about axis 82. In order to gain a better visualization of the twisting suffered by torsional member 20 reference is made to Figure 6-3(d) of *Mechanics of Materials* by W. Riley, L. Sturges and D. Morris; John Wiley & Sons, 1999 (a copy of pages 272 – 275 thereof is attached hereto as Appendix B for the Board’s ready reference). The twisting of torsional member 20 is as shown in Figure 6-3(d) of *Mechanics of Materials*.

Returning now to the so called “void area,” upon assembly of the arrangement shown in Figure 2 of Taig, this “void area” is located coincident with the periphery of the shaft that makes up the input member 16. However, this “void area” is *just* that area, or location, in which the sensor of the present application is in fact found. This is clearly seen in Figures 14A – 14D of the application as filed. Thus, even if tabs 70 and 74 of Taig are displaced with respect to one another in response to an applied torque, as the Examiner seems to be saying in the above quote, there is no material between these tabs. In other words, there is simply nothing in this “void area” to *act* as a sensor. Thus, Taig is missing an element of Claim 1, namely *a piezoresistive sensor positioned within and along the length of a slot which is parallel to the axis of a shaft and located at a single peripheral location about the surface of the shaft*.

In order to more fully grasp the distinction between the nature of the sensor in Taig and that of the present application, it will be instructive to also examine the stresses that are set up in the torsional plate 20 of Taig vs. the stresses found in the sensor 120 of the

present application. The stresses set up in the torsional plate 20 of Taig as a result of the torsional loading, are at an angle with respect to the axis 82. This follows from the twisting shown in Figure 6-3(d) of *Mechanics of Materials*. In stark contrast, the stresses that result from the loading applied to the sensor of the present application are parallel to the axis of the beam, e.g. they are compressive on one side of the beam and tensile on the opposite side. In the cantilever beam of the present application, one end of the beam moves with respect to the other as it is subject to a load as shown in Figure 4 of the application. The applied load is perpendicular to the length of the beam. There is absolutely *no* torsional loading of the sensor. The only loading of the sensor in the present application is as a cantilever beam. A cantilever beam "is a member with one end projecting beyond the point of support, free to move in a vertical plane under the influence of vertical loads placed between the free end and the support." *Handbook of Engineering Fundamentals*, O. W. Eshbach and M. Souders, Ed., John Wiley & Sons, 3<sup>rd</sup> Ed. 1975. (Appendix C.).

As noted above, the strain gauge 94 in Taig, is in fact situated over the *central portion* 66 of the torsion member 20 and thus also *straddles* axis 82. The torsion member 20 *twists* about axis 82, i.e. it is a member under *torsion*. Because of the fact that the strain sensor 94 is located along the axis 82, and due to the nature of the stresses set up in the torsional plate 20, the strain sensor 94 would need to be set off *at an angle* with respect to the axis 82 (i.e. *not parallel to the axis*); much as the conventional manner in the strain sensor shown in the U. S. patent to H. Brier (2,754,465). However, these sensors, and thus the sensor 94 of Taig, do *not* respond as cantilever beams.

Thus, it must be seen that the sensor 94 in Taig is neither *responding as a cantilever beam* as required by Claim 1, nor is it *positioned within and along the length of a slot* which is *parallel to the axis of a shaft* and located at a single peripheral location about the surface of the shaft, also as required by Claim 1.

Thus, based upon the foregoing remarks, the Appellants respectfully submit that Claim 1 as amended in the response to the first Office Action, clearly distinguishes over Taig and therefore stands in condition for allowance. Claims 2 and 9 which depend

directly from Claim 1 are therefore also allowable for at least the same reasons as set forth with regard to Claim 1.

**B. Claims 3 - 8 are patentable under 35 U.S.C. §103(a).**

For an obviousness rejection to be proper, the Examiner must meet the burden of establishing a *prima facie* case of obviousness. *In re Fine*, U.S.P.Q.2d 1596, 1598 (Fed. Cir. 1988). The Examiner must meet the burden of establishing that *all* elements of the invention are disclosed in the prior art; that the prior art relied upon, coupled with knowledge generally available in the art at the time of the invention, must contain some suggestion or incentive that would have motivated the skilled artisan to modify a reference or combine references; and that the proposed modification of the prior art must have had a reasonable expectation of success, determined from the vantage point of the skilled artisan at the time the invention was made. *In re Fine*, 5 U.S.P.Q.2d 1596, 1598 (Fed. Cir. 1988); *In re Wilson*, 165 U.S.P.Q. 494, 496 (C.C.P.A. 1970); *Amgen v. Chugai Pharmaceuticals Co.*, 927 U.S.P.Q.2d, 1016, 1023 (Fed. Cir. 1996). Moreover, the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 USPQ2d 1430 (Fed. Cir. 1990).

The Appellants respectfully submit that there is no combination of Taig, Brosh and Buhl that teaches, nor even suggests, a piezoresistive sensor *responsive as a cantilever beam*; nor is there any combination of Taig, Brosh and Buhl that teaches, nor even suggests a piezoresistive sensor *positioned within and along the length of a slot which is parallel to the axis of a shaft and located at a single peripheral location about the surface of the shaft*, both of which are required by Claims 1 and 3.

In fact, Taig teaches *away* from the invention encompassed by Claim 1 by virtue of the torsion member 20 being “elongated, and flat with a central portion 66 of reduced lateral dimension”, i.e., the so called “void area.” (*Col. 3, lines 45 – 47*). The present application in fact fills the technological vacuum of the “void area” explicitly *created* by, and certainly not addressed by, Taig; nor for that matter Brosh or Buhl.

Thus, the Examiner has not met the burden of establishing that *all* elements of the invention are disclosed in the prior art and has therefore not met the burden of establishing a *prima facie* case of obviousness with respect to Claim 3, which depends from Claim 1. Claims 4 - 8 which depend variously from Claim 3 are therefore also allowable for at least the same reasons as set forth with regard to Claim 3.

**C. Conclusion**

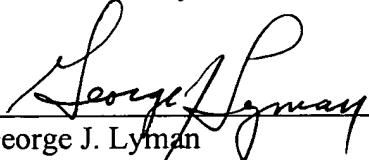
For the reasons cited above, Appellants respectfully submit that the rejections are improper and request reversal of the outstanding rejections. If there are any additional charges with respect to this Appeal or otherwise, or otherwise, please charge them to Deposit Account No. 06-1130 maintained by Appellants' attorneys.

Respectfully submitted,

THADDEUS SCHROEDER, et al.

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9. **APPENDIX A**

**Appealed Claims**

1. An automotive steering system comprising:
  - a shaft linked to a set of road wheels, the shaft including a slot parallel to the axis of the shaft and located at a single peripheral location about the surface of the shaft;
  - a piezoresistive sensor positioned within and along the length of the slot and responsive as a cantilever beam to torque applied to the shaft and operative thereby to provide as output a signal indicative of the applied torque;
  - a controller in signal communication with the sensor and operative thereby to accept as input from the sensor the signal indicative of the torque applied to the shaft; and
  - a motor coupled to the shaft and in signal communication with the controller and operative thereby to accept as input from the controller a command to apply torque to the shaft.
2. The automotive steering system as set forth in Claim 1 wherein the shaft includes
  - a first section;
  - a second section linked to the set of road wheels; and
  - a third section joining the first and second sections.
3. The automotive steering system as set forth in Claim 1 wherein the piezoresistive sensor comprises at least one piezosensitive element coupled to a ceramic substrate.
4. The automotive steering system as set forth in Claim 3 wherein the at least one piezosensitive element is part of an electric circuit.

5. The automotive steering system as set forth in Claim 3 wherein the at least one piezosensitive element is connected to an amplifier operative thereby to provide as output the signal indicative of the torque applied to the shaft.

6. The automotive steering system as set forth in Claim 4 wherein the at least one piezosensitive element includes a piezoresistor.

7. The automotive steering system as set forth in Claim 4 wherein the electric circuit comprises a bridge circuit.

8. The automotive steering system as set forth in Claim 7 wherein the bridge circuit is a wheatstone bridge.

9. The automotive steering system as set forth in Claim 1 wherein the shaft includes

a hub connected to the shaft; and

a steering wheel connected to the hub.

## Chapter 6

# Torsional Loading of Shafts

From: *Mechanics of Materials*  
By: W. Riley, L. Sturges and D. Morris  
John Wiley & Sons, 1999

### 6-1 INTRODUCTION

The problem of transmitting a torque (a couple) from one plane to a parallel plane is frequently encountered in the design of machinery. The simplest device for accomplishing this function is a circular shaft such as that connecting an electric motor with a pump, compressor, or other machine. A modified free-body diagram (the weight and bearing reactions are not shown because they contribute no useful information to the torsion problem) of a shaft used to transmit a torque from a driving motor *A* to a coupling *B* is shown in Fig. 6-1. The resultant of the electromagnetic forces applied to armature *A* of the motor is a couple resisted by the resultant of the bolt forces (another couple) acting on the flange coupling *B*. The circular shaft transmits the torque from the armature to the coupling. Typical torsion problems involve determinations of significant stresses in and deformations of shafts.

A segment of the shaft between transverse planes *a-a* and *b-b* of Fig. 6-1 will be studied. The complicated stress distributions at the locations of the torque-applying devices are beyond the scope of this elementary treatment of the torsion problem. A free-body diagram of the segment of the shaft between sections *a-a* and *b-b* is shown in Fig. 6-2 with the torque applied by the armature indicated on the left end as *T*. The resisting torque *T<sub>r</sub>* at the right end of the segment is the resultant of the moment of the differential forces *dF* acting on the transverse plane *b-b*. The force *dF* is equal to  $\tau_p dA$  where  $\tau_p$  is the shearing stress on the transverse plane at a distance  $\rho$  from the center of the shaft and *dA* is a

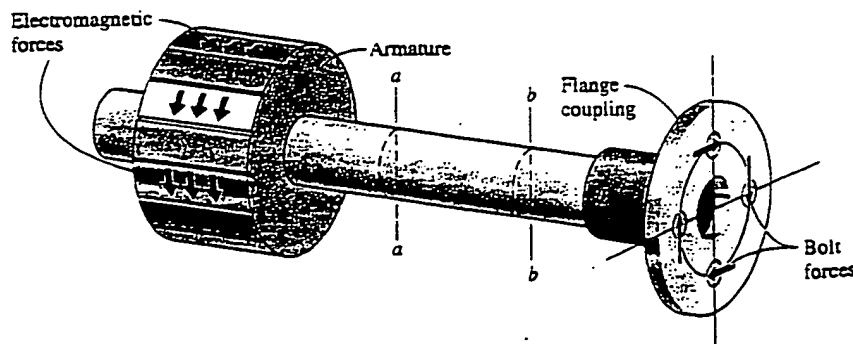


Figure 6-1

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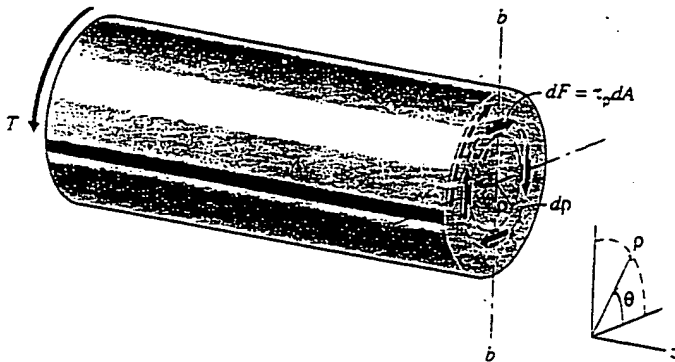


Figure 6-2

differential area. For circular sections, the shearing stress on any transverse plane is always perpendicular to the radius to the point. If the shaft is in equilibrium, a summation of moments about the axis of the shaft indicates that

$$T = T_r = \int_{\text{area}} \rho dF = \int_{\text{area}} \rho \tau_{\rho} dA \quad (6-1)$$

The law of variation of the shearing stress on the transverse plane ( $\tau$  as a function of radial position  $\rho$ ) must be known before the integral of Eq. 6-1 can be evaluated. Thus, the problem of determining the relationship between torque and shearing stress is statically indeterminate. Recalling the procedures developed in Chapter 5, the solution of a statically indeterminate problem requires the use of the equation of equilibrium (Eq. 6-1 for torsion), an analysis of deformation, and the relationship between stress and strain.

In 1784 C. A. Coulomb, a French engineer, developed (experimentally) a relationship between applied torque and angle of twist for circular bars.<sup>1</sup> In a paper published in 1820,<sup>1</sup> A. Duleau, another French engineer, derived the same relationship analytically by making the assumption that a plane section before twisting remains plane after twisting and a diameter remains straight. Visual examination of twisted models indicates that these assumptions are correct for circular sections either solid or hollow (provided the hollow section is circular and symmetrical with respect to the axis of the shaft), but incorrect for any other shape. Compare, for example, the distortions of rubber models with circular and rectangular cross sections shown in Fig. 6-3. Figure 6-3b shows the circular shaft after loading, and illustrates that plane sections remain plane. For the rectangular shaft, plane sections before loading (Fig. 6-3c) become warped after loading (Fig. 6-3d).

## 6-2 TORSIONAL SHEARING STRAIN

If a plane transverse cross section of a circular shaft before twisting remains plane after twisting and a diameter of the section remains straight, the distortion of the shaft of Fig. 6-2 will be as indicated in Fig. 6-4a, where points  $B$  and  $D$  on a common radius in a plane move to points  $B'$  and  $D'$  in the same plane and still on the same radius. The angle  $\theta$  is called the *angle of twist*. The surface  $ABB'$

<sup>1</sup>From *History of Strength of Materials*, S. P. Timoshenko, McGraw-Hill, New York, 1953.

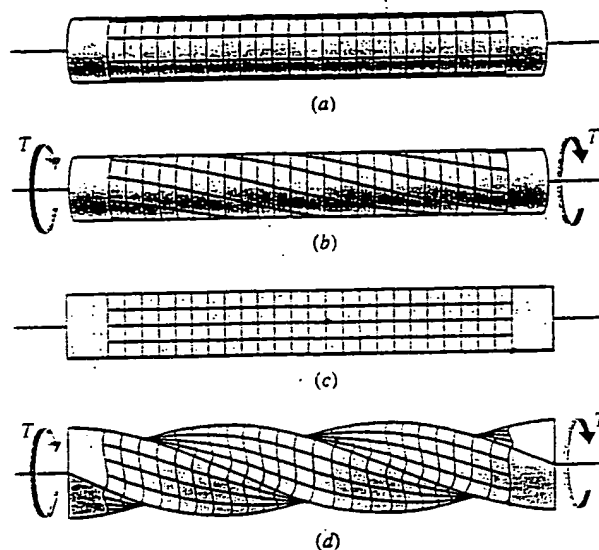


Figure 6-3

of Fig. 6-4a is shown in plan view in Fig. 6-4b, in which a differential element of the material at  $B$  (Fig. 6-4c) is distorted at  $B'$  due to shearing stress (Fig. 6-4d). Clearly, the angle  $\phi$  of Fig. 6-4b is the same as the shearing strain  $\gamma_c$  of Fig. 6-4d. Similar figures could be drawn for the surface  $EDD'$ . It is recommended that the reader review the concept of shearing strain in Section 3-2.

At this point the assumption is made that all longitudinal elements ( $AB$ ,  $ED$ , etc.) have the same length  $L$  (which limits the results to straight shafts of constant diameter). From Fig. 6-4, the shearing strain  $\gamma_\rho$  at a distance  $\rho$  from the

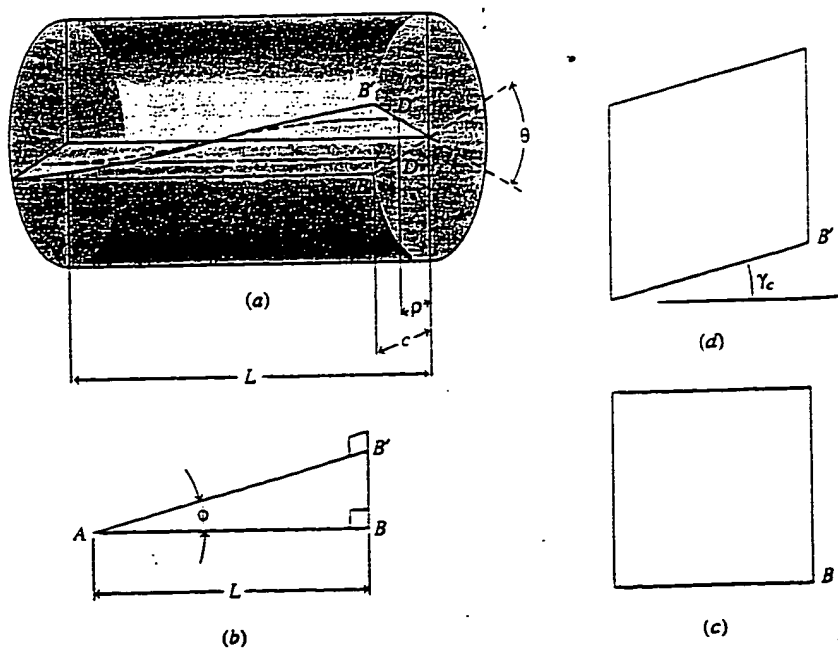


Figure 6-4

center of the shaft and  $\gamma_c$  at the surface of the shaft ( $\rho = c$ ) are related to the angle of twist  $\theta$  by

$$\tan \gamma_c = \frac{BB'}{AB} = \frac{c\theta}{L}$$

and

$$\tan \gamma_\rho = \frac{DD'}{ED} = \frac{\rho\theta}{L}$$

or, if the strain is small ( $\tan \gamma \cong \sin \gamma \cong \gamma$ ,  $\gamma$  in radians),

$$\gamma_c = \frac{c\theta}{L} \quad (6-2a)$$

and

$$\gamma_\rho = \frac{\rho\theta}{L} \quad (6-2b)$$

Combining Eqs. 6-2a and 6-2b gives

$$\theta = \frac{\gamma_c L}{c} = \frac{\gamma_\rho L}{\rho}$$

which indicates that the shearing strain

$$\gamma_\rho = \frac{\gamma_c}{c} \rho \quad (6-3)$$

is zero at the center of the shaft and increases linearly with respect to the distance  $\rho$  from the axis of the shaft. Equation 6-3 is the result of the deformation analysis of a circular shaft subjected to torsional loading. This equation can be combined with Eq. 6-1 once the relationship between shearing stress  $\tau$  and shearing strain  $\gamma$  is known.

Up to this point, no assumptions have been made about the relationship between stress and strain or about the type of material of which the shaft is made. Therefore, Eq. 6-3 is valid for elastic or inelastic action and for homogeneous or heterogeneous materials, provided the strains are not too large ( $\tan \gamma \cong \gamma$ ). Problems in this book will be assumed to satisfy this requirement.

### 6-3 TORSIONAL SHEARING STRESS—THE ELASTIC TORSION FORMULA

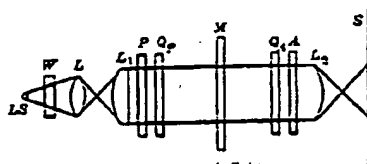
If the assumption is now made that Hooke's law applies (the accompanying limitation is that the stresses must be below the proportional limit of the material), the shearing stress  $\tau$  is related to the shearing strain  $\gamma$  by the expression  $\tau = G\gamma$  (Eq. 4-1c). Then, multiplying Eq. 6-3 by the shear modulus (modulus of rigidity)  $G$  gives

$$\tau_\rho = \frac{\tau_c}{c} \rho \quad (6-4)$$

When Eq. 6-4 is substituted into Eq. 6-1, the result is

$$T = T_r = \frac{\tau_c}{c} \int \rho^2 dA = \frac{\tau_c}{\rho} \int \rho^2 dA \quad (a)$$

Photoelastic Methods involve the construction of a model of the prototype from an isotropic transparent material such as Bakelite, Celluloid, and glass. When these substances are subjected to stress they become doubly refracting, and plane-polarized light on passing through the material is changed into two component mutually perpendicular rays which are parallel and perpendicular to the directions of stress. The emergent rays will be out of phase, depending on the stress and the thickness of the material. A photo-



LS = monochromatic light source  
L = collimating lens  
 $L_1, L_2$  = lenses  
P = polarizer  
A = analyzer  
 $Q_1, Q_2$  = quarter wave plates  
M = stressed model  
S = screen or camera

FIG. 12. Polariscope

graph of the emergent rays gives light and dark fringes indicative of the distribution of the principal stresses. A schematic diagram of one method is shown in Fig. 12. This procedure is used to measure static stress.

Summary of Strain-measuring Devices. Table 3 presents a convenient summary of the more common commercial instruments. Detailed discussion of the various methods may be found in the references cited in the last column of Table 3 and also in Refs. 3 and 4.

## REFERENCES

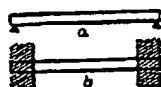
1. ROARK, R. J., *Formulas for Stress and Strain*, New York, McGraw-Hill, 4th ed., 1935.
2. MASON, J., *Mechanical Properties of Materials and Design*, New York, McGraw-Hill, 1942.
3. Proc. Society for Experimental Stress Analysis.
4. ROSENTHAL, H. C., *Mechanical Measurements by Electrical Methods*, Instruments Publishing Co.

## BEAMS

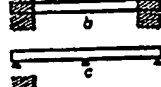
### 15. THEORY OF FLEXURE

**Types of Beams.** A beam is a bar or structural member subjected to transverse loads that tend to bend it. Usually beams are horizontal bars designed to carry vertical loads, but any structural member acts as a beam if bending is induced by external transverse forces.

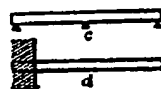
A Simple Beam (Fig. 1a) is a horizontal member that rests on two supports at the ends of the beam. All parts between the supports have free movement in a vertical plane under the influence of vertical loads.



A Fixed Beam, Constrained Beam, or Restrained Beam (Fig. 1b) is one that is rigidly fixed at both ends or rigidly fixed at one end and simply supported at the other.



A Continuous Beam (Fig. 1c) is a member resting on more than two supports.



A Cantilever Beam (Fig. 1d) is a member with one end projecting beyond the point of support, free to move in a vertical plane under the influence of vertical loads placed between the free end and the support.

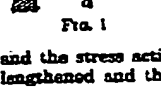


FIG. 1

**Phenomena of Flexure.** When a simple beam bends under its own weight, the fibers on the upper or concave side are shortened and the stress acting on them is compression; the fibers on the under or convex side are lengthened and the stress acting on them is tension. In addition to the longitudinal stresses acting on the fibers, shear exists along each cross section, the intensity of the shear being greatest along the sections at the two supports and zero at the middle section.

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